TEACHING AND LEARNING ROBOTICS WITH INTERNET TELEOPERATION

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Virtual laboratories offer many advantages for the teaching of technological subjects, such as flexibility in time-tables and student access to expensive and limited equipment. However, it is also important to evaluate the acceptability of such laboratories by the students and the effect they have on teaching. In this article, we present the main tool of the virtual laboratory used by the authors in teaching a Robotics subject, and which allows the simulation and tele-operation of a robot arm. The main results of a study on the impact of the virtual laboratory on the students and the teaching-learning process is also described in detail.

1 Introduction

Teaching of practical subjects or courses of robotics requires traditionally equipment expensive and many times insufficient to be used for many students simultaneously, as the robots and its controllers are. Moreover, it is possible these equipments can be damaged if they are used improperly. Other problem derived from requiring a laboratory with the appropriate equipment to carry out the practices is the need of that the students have to go to these laboratories in some strict schedules. In this way, the necessity of alternative methods arises [2,5].

Nowadays, it is being shown that the new technologies as the Internet, the tele-operation of systems or the virtual reality allows the student to carry out the practical exercises from other places (as home) without the above mentioned problems by using the virtual laboratories [1,3,9]. Other advantages of these systems of remote practice are that they also allows self-evaluation mechanisms for their acquired knowledge and that they allow a great number of students to have access to expensive and scarce equipment [6,8].

But in setting-up a virtual laboratory, apart from the above-mentioned advantages, one must also consider other important aspects, such as the actual its acceptance by the students, and the effects it has on their the learning. To evaluate these aspects surveys can be carried out with the students how use the virtual laboratory and evaluate their performance, in comparison whit the other students.

The authors of this article use a virtual laboratory which they have developed them self for teaching a subject on robotics for engineering and have been evaluating the results for several years. The presentation of the main tool of this laboratory will be analysed in the following section. Afterwards, in section three, the scope of the study carried out during the 2002/03 academic year will be presented together with the most important statistics. Finally, in section four, the main conclusions are presented [4,11].

2 ROBOLAB: Simulating and tele-operating an industrial robot arm

The most important software tool in the virtual laboratory, and with is directly related to Robotics is a system called ROBOLAB, with have been developed by our research team. The system permits the students to work with a simulation of and industrial robot and carry out operations whit the real robot through tele-operation [2].

The only means that the student requires are a computer connected to the Internet, a web client program and some required software components. With these means the student can access to a web page with a Java applet that affords access to the functions offered by ROBOLAB. The first version of the applet also provides a virtual reality simulation based on VRML (Virtual Reality Modelling Language) which gives a 3-dimensional representation of the robot-setting and its workspace (Fig. 1-a) [2,7]. To facilitate its installation, avoid compatibility software compatibility problems and offer the students a simpler interface, another version that carries out the simulation in Java 3D have recently been created (Fig. 1-b).

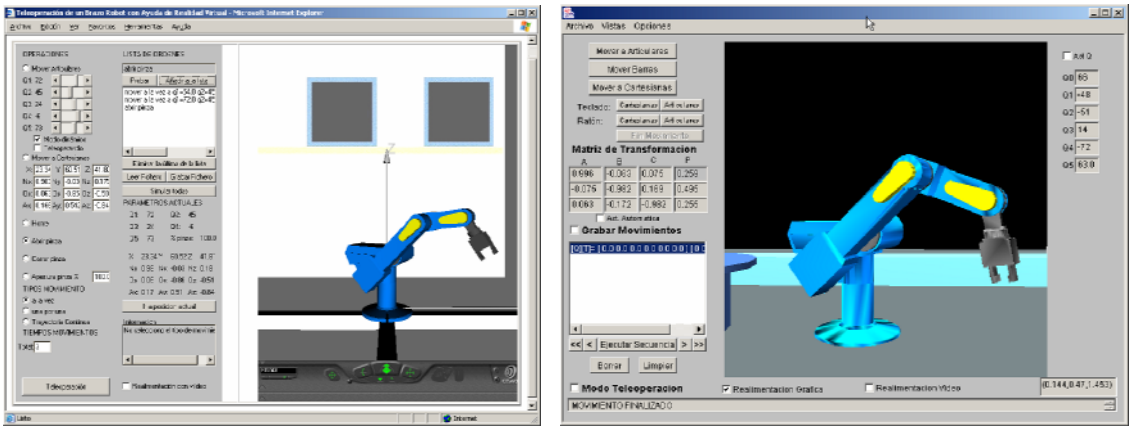

Figure 1. User interface of ROBOLAB applet: a) Java-VRML version, b) Java-3D version

With regard to equipment in the laboratory (Fig. 2), the most important feature is the Scorbot ER-IX (Intelitek) robot arm with 5 DOF and a gripper, together with its controller. These are the only two pieces of the equipment that requires any considerable investment. The remaining pieces are commercial items that are readily available on the market. The "robot server" is a PC that manages the commands sent to the robot and obtains information about its current state to allow an on-line feed-back. The "web server" is another PC that affords the web services from the Internet, supplies the self-evaluation questionnaires and forms and accepts the results. It also manages the users login and store the statistics of their practice. Furthermore, it is "video server" with gives the option of a video stream feed-back for tele-operation [2,7].

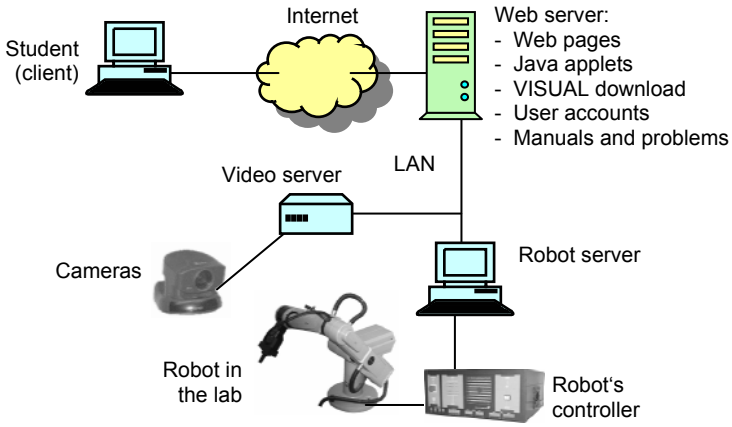

Figure 2. Architecture of ROBOLAB.

The student first does the exercises on the simulation and then, after checking that the results are correct, can execute their in the real system by means of the tele-operation option. This guarantees a good use of the real system and increases it useful life-span. Thanks to the simulation, the students are able to practice and carry out correct movement sequences. Once a correct simulation has been effected, the student can request the "web server" to remote execute the movement sequences with the real robot. To do so the student must identify himself as an authorized user. The "web server" also manages the access of several users to the robot, guaranteeing their orderly access.

To verify the movement of the real robot, the applet has different feed-back options, two of which are outstanding. The first one is a compressed video stream, generated by the "video server" and sent to the student' computer while the robot is executing the movement sequence [7]. The second one, is that the simulation in the students computer is updated with information about the current state of real robot's joints received online from the "robot's controller" [10]. The second option allows a fluid tele-operation with a lower bandwidth requirement the first one.

3 Analyzing learning with the virtual laboratory

ROBOLAB has been use since the 1999/2000 academic year in practice groups for the Robotics subject "Technology and Control of Robots and Sensorial Systems" with is taught in Computer Science Engineering at the University of Alicante. To evaluate the virtual laboratory's acceptability and its effect on learning, a statistical study has been carried out during 2002/03 academic year on fifty students from different practice groups. This study complements another one carried out during the previous academic year [4], and evaluates not only questionnaires on the laboratory's acceptability and use but also on the professors' qualifications with regard to the technical questions related to the experiments. The study was focused on theses two practical exercises:

- Practice 1. ROBOLAB training and basic concepts of Robotics.
- Practice 2. Design of trajectories for a robot. Simulation and tele-operation through ROBOLAB.

To do the practices, the students had two options. They could either go personally to the laboratory at the school to resolve the questions and hand-in their results, or they could do the exercises at home or anywhere else, through the Internet, at a time that is most convenient to them. In either case, the students should fill-in a questionnaire about the use of the virtual laboratory and their opinion.

3.1 Results for Practice 1

The first results obtained where that only 20% of the students had opted to do their practice at home in contrasts to 17% who preferred to do it at the university's laboratory (Fig. 3-a). The students who preferred to do the practice outside (29%) complained of a lag of time and inconvenience. We should point out that, in the computer science career, many of the students combine study and work. The main reason that the students choose to do their practice at the university's laboratory is that their considered the teachers explanations to be vital (65% of the questionnaires). Another reason is that they considered the working conditions to be better: the software was already installed and the speed of access was faster.

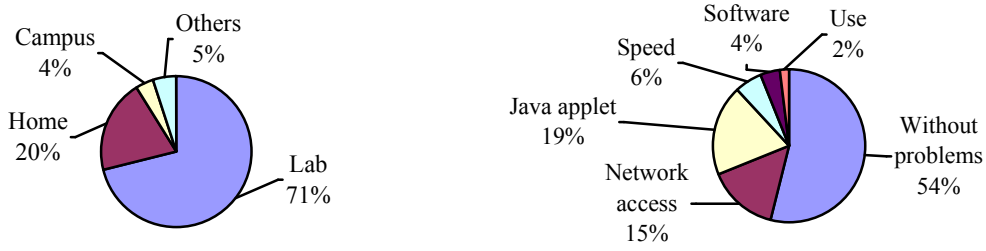

Figure 3. a) Location of the student. b) Problems that students have doing the practice.

Figure 3-b shows the main problems faced by the students in doing the experiments. 54% did their experiments without any problem. The most common problems were the loading of the applet (19%), due to inappropriate versions of the software, and the access to the net from outside of the university (15%).

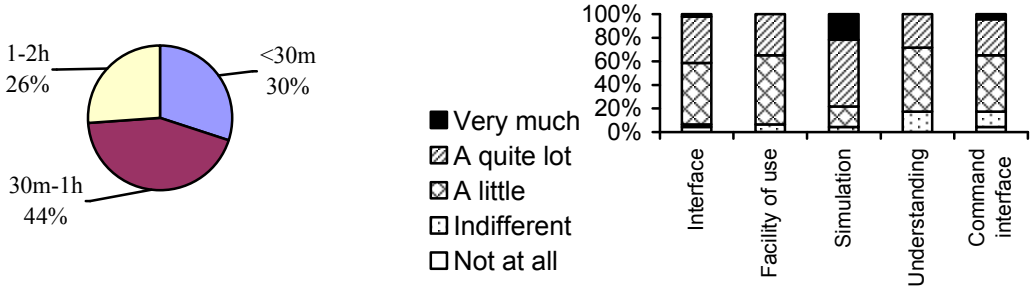

Figure 4. a) Time required by the student. b) Appraisal of ROBOLAB.

Considering that the estimated time of the practice was 2 hours, and the majority of students did it in 1 hour (Fig. 4-e), we can conclude that learning with ROBOLAB is quite simple. Figure 4-b presents the degree to with the students like the ROBOLAB tool. It should be noted that, of the five features evaluated, more than 80% of the students rated it positively, with justifies its inclusion in virtual laboratory.

3.2 Results for Practice 2

In the first place, a considerable reduction is noticed in the number of students who opted to do the Practice 2 at the university's laboratory (57%), in comparison to those in Practice 1 (71%). As such, 33% decided to do their Practice 2 experiments at home in contrast to 20% in Practice 1 (Fig. 5-a).

With regard to the time that the students dedicated to that part of the practice in which they has to use the simulator and the tele-operation, 62% needed 90 minutes or less, which was the actual estimated time (Fig. 5-b). This gives us an idea of the students' real level of understanding of the use of ROBOLAB, after been introduced to their in Practice 1.

Figure 5. a) Location of the student. b) Time required by the student.

3.3 Other results

It has been shown that 87% of the students had access to the Internet outside of the university during the 2002/03 academic year (Fig. 6-a). The previous year, only 62% had personal access, which indicates a increase a considerable increase.

The survey has also shown that most of the students preferred to work at the university's laboratory, although the majority also preferred to give-in the results of their practices through the Internet (Fig. 6-b).

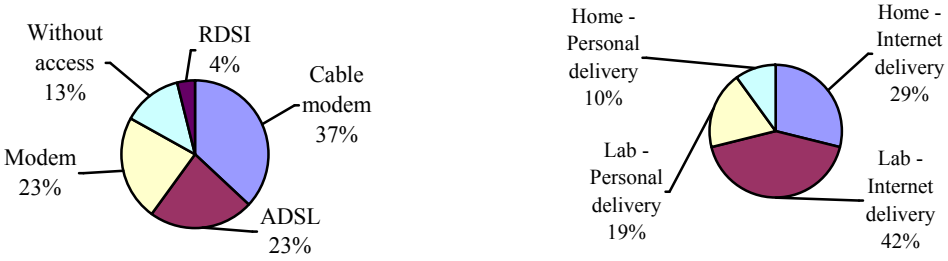

Figure 6. a) Internet access used by the student. b) Preferences regarding practice and delivery of results.

Finaly, we must point out that the great majority of the students are no familiar with any other type of virtual laboratory with industrial robot simulators that are similar to the one use here, although 25% have previously used some type of mobile robot simulators or have heard about some type of robot arm simulators for commercial use.

4 Conclusions

Based on the studies presented here an important conclusion can be drawn. Although there are a great number of students who happily accept a virtual laboratory that offers them a flexible time table for their experiments, many also prefer to have a real laboratory at the university where they can work in coordination their class-mates and have the support of a teacher. In other words, the students considerer the

virtual laboratory to be a valuable complement to the teacher and traditional teaching, but never as substitute for them.

On the other hand, it has been shown that the virtual laboratory is new to the students, although it is well accepted. Their simple use helps the student to save time in learning it and concentrate on the more important aspects of the course. The remote access to costly tools and resources like robots is positive and interesting, since they make practice more attractive and real in comparison to a mere simulation.

In any case, it must be assort that the software required for the student's computers is accessible and easy to install, and that the tools work correctly in different types of computers and operating systems. To do so, Java is a very good option.

Considering the advantages the virtual laboratory offers and the student's need to work in groups and have a teacher available, our research team is working on web environments that offer not only virtual tools but also ones that allow the students to share their experiences and their results, while having a virtual teaching support. As such a greater academic success will be afforded by virtual laboratories.

5 Acknowledgements

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